

SEMICONDUCTOR DYNAMIC QUANTITY SENSOR

REFERENCE TO RELATED APPLICATIONS

This application is based on Japanese Patent
5 Application No. 2002-216648 filed on July 25, 2002, the
contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION:

10 The present invention relates to a semiconductor
dynamic quantity sensor for detecting a dynamic force.

2. DESCRIPTION OF RELATED ART:

A semiconductor dynamic quantity sensor includes a
15 semiconductor substrate and a bridge circuit. The
semiconductor substrate has a diaphragm that changes its shape
in accordance with an application of a dynamic force, such as
a pressure and acceleration force. The bridge circuit has
gauge resistors formed on the substrate. Resistances of the
20 gauge resistors vary as the shape of the diaphragm 14 changes.
The sensor produces a sensor output and a diagnostic output
through the use of the bridge circuit for a fault diagnosis
that is performed based on a comparison of the outputs.

In such a sensor, the outputs for the dynamic quantity
25 measurement and for the fault diagnosis can be produced by a
single bridge circuit. As a result, the sensor is reduced in
size.

The applicant filed a related Japanese patent application No. JP-2001-221697. FIG. 9 shows an equivalent circuit of a bridge circuit described in the related art. The bridge circuit has a Wheatstone bridge circuit constructed of four gauge resistors Ra, Rb, Rc, and Rd that are connected in series to form a quadrangular closed circuit. Resistors of wiring patterns H1 to H10 between the gauge resistors are shown.

Terminals A, B, C, and D are electrically connected to respective junctions of the wiring patterns H1 and H10, H31 and H31, H5 and H6, and H81 and H82. The terminals A and D are used for inputting an input voltage (input signal) Vin. The terminals B and C are used for outputting a first differential voltage (output signal) Vout1. The input terminals A and D are electrically connected to a power supply (first electric potential) and the ground (second electric potential), respectively.

Each of the four gauge resistors Ra to Rd is equally divided into two divisional gauge resistors. For instance, the gauge resistor Ra, which is provided between the input terminal A and the output terminal B, is divided into the divisional gauge resistors Ra1 and Ra2. Other gauge resistors Rb to Rd are divided into two gauge resistors Rb1 and Rb2, Rc1 and Rc2, and Rd1 and Rd2, respectively in the same manner as the gauge resistor Ra.

The gauge resistor Ra has a first midpoint between the divisional gauge resistors Ra1 and Ra2. The gauge resistor Rb

has a second midpoint between the divisional gauge resistors Rb1 and Rb2, and the second midpoint is electrically connected to a middle terminal B1. The gauge resistor Rc has a third midpoint between the divisional gauge resistors Rc1 and Rc2.

5 The gauge resistor Rd has a fourth midpoint between the divisional gauge resistors Rd1 and Rd2, and the fourth midpoint is electrically connected to a middle terminal C1.

The middle terminals B1 and C1 make a combination of the midpoints at which an equal electric potential is measured
10 when no pressure is applied to the bridge circuit. The combination of the middle terminals B1 and C1 is used as the output terminals for the diagnosis. A second potential difference Vout2 between the middle terminals B1 and C1 is used as the diagnostic output to detect a fault of the sensor.

15 When the diaphragm changes its shape by applying the dynamic force in condition that the input signal Vin is inputted into the bridge circuit, the four gauge resistors Ra to Rd lose a balance in electrically. The first differential voltage (output signal) Vout1 varies in response to the amount
20 of the applied dynamic force. The first differential voltage Vout1 is supplied to an external circuit to detect intensity of the dynamic quantity.

The fault is detected by that the first differential voltage Vout1 is compared with the second differential voltage
25 Vout2. The first differential voltage Vout1 is used as the sensor output. Since each divisional gauge resistors Ra1 to Rd2 has the same resistance, a first ratio between the

divisional gauge resistors R_{d1} and R_{d2} is 1:1, and a second ratio between the divisional gauge resistors R_{b1} and R_{b2} is 1:1. Accordingly, in a normal condition, the second differential voltage V_{out2} is always a half voltage of the first differential voltage V_{out1} .

However, in an unusual condition that an irregular stress is applied to the diaphragm or the divisional gauge resistors R_{a1} to R_{d2} are broken, the first ratio and the second ratio are deviated from 1:1. As a result, in the unusual condition, the second differential voltage V_{out2} for the diagnosis is not a half voltage of the first differential voltage V_{out1} . That is, a relation between the differential voltages V_{out1} and V_{out2} in the unusual condition is different from the relation in the normal condition. This provides the judgment of the fault in the sensor.

Offset voltages exist in both the first differential voltage V_{out1} and the second differential voltage V_{out2} in the bridge circuit. The offset voltages, which are generated by the first and second differential voltages V_{out1} and V_{out2} when the dynamic force is not applied to the diaphragm, cause an error of detection. If resistors of the wiring patterns $H1$ to $H10$ that connect between the divisional gauge resistors R_{a1} to R_{d2} are zero or the identical in the bridge circuit, resistances of the bridge circuit are determined by a pattern of the circuit or a circuit layout. Further, if each of the resistances of the divisional gauge resistors is identical, the offset voltage does not exist in the sensor output and the

diagnostic output.

However, in reality, resistances of the wiring patterns H1 to H10 exist in each of the divisional gauge resistors R_{a1} to R_{d2} and between the terminals A, B, C, D, B₁, and B₂. If the resistances of the wiring patterns H1 to H10 are identical with each other, the offset voltage is equal to zero. However, it is difficult to adjust the resistances of the wiring patterns to be equal to each other because of the pattern of the wiring patterns and the circuit layout.

In such a sensor, an external resistor is connected to the bridge circuit, and a resistance of the external resistor is adjusted by a trimming operation so that the offset voltage becomes a certain voltage. However, it is difficult to adjust the two offset voltages with respect to the sensor output and the diagnostic output by the connection of the external resistor.

FIG. 10 shows an equivalent circuit of the bridge circuit shown in FIG. 9 along with the external resistors. Suppose that the offset voltage of the second differential voltage V_{out2} is equal to zero, and the offset voltage of the first differential voltage V_{out1} is a certain voltage that is not equal to zero.

External resistors R_{g1} and R_{g2} are provided to the bridge circuit to adjust the offset voltage of the first differential voltage V_{out1}. This causes a variation of the electric potential of the output terminal B with reference to the output terminal C because an electrical current between

the terminals A and D varies. As a result, the offset voltage of the first differential voltage V_{out1} is adjusted to be equal to zero.

5 However, an electrical potential of the terminal B1 also varies with reference to the electrical potential of the terminal C1 due to the variation of the electrical current between the terminals A and D by the connection of the external resistors R_{g1} and R_{g2} . As a result, the offset voltage of the second differential voltage V_{out2} for the
10 diagnostic output turns not equal to zero.

Similarly, the two offset voltages V_{out1} and V_{out2} are not adjusted simultaneously even if external resistors R_{v1} and R_{v2} are provided to a high voltage potential side of the bridge circuit. That is, either the offset voltage V_{out1} or
15 V_{out2} in the bridge circuit is adjusted with the external resistors, but the two offset voltages V_{out1} and V_{out2} are not adjusted to be equal to zero simultaneously.

SUMMARY OF THE INVENTION

20 The present invention therefore has an object to provide a semiconductor dynamic quantity sensor that detects a dynamic quantity and a fault diagnosis through the use of a single bridge circuit, more particularly to adjust an offset voltage of a sensor output and a fault diagnostic output as
25 appropriate.

According to one aspect of the present invention, a semiconductor dynamic quantity sensor has a semiconductor

substrate, a bridge circuit, a couple of first output terminals used as a sensor output, and a couple of second output terminals used as a fault diagnostic output. The bridge circuit has four gauge resistors formed on the substrate, and each of the four gauge resistors has a plurality of divisional gauge resistors. The first output terminals are connected to midpoints between the gauge resistors. The second output terminals are connected to wiring patterns between the divisional gauge resistors. At least one of the first output terminals has plurality terminals connected to different positions of the midpoint. At least one of the second output terminals has plurality terminals connected to different positions of the wiring pattern. Accordingly, offset voltages of the sensor output and the fault diagnostic output can be adjusted appropriately when at least one of the plurality terminals are selected as appropriate.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

FIG. 1 is a plan view of the semiconductor pressure sensor according to an embodiment of the present invention;

FIG. 2 is a sectional side view taken on line II-II in FIG. 1;

FIG. 3 is a simplified plan view of FIG. 1;

FIG. 4 is an enlarged view of FIG. 1 in a vicinity of a gauge wiring pattern H3;

FIG. 5 is an enlarged view of FIG. 1 in a vicinity of a gauge wiring pattern H2;

5 FIG. 6 is an enlarged view of FIG. 1 in a vicinity of a gauge wiring pattern H8;

FIG. 7 is an enlarged view of FIG. 1 in a vicinity of a gauge wiring pattern H7;

FIG. 8 is an equivalent circuit diagram of the sensor;

10 FIG. 9 is an equivalent circuit diagram according to a related art; and

FIG. 10 is an equivalent circuit diagram along with external resistors according to the related art.

15 DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The preferred embodiments of the present invention will be explained with reference to the accompanying drawings. Referring to FIG. 1 and FIG. 2, the sensor S1 includes a semiconductor substrate 10 made from a semiconductor material
20 such as silicon. The sensor S1 is manufactured by well-known semiconductor production techniques. A top surface 11 of the semiconductor substrate is a $\langle 110 \rangle$ plane of a silicon single crystal substrate. The $\langle 110 \rangle$ plane is shown in FIG. 1. An axis X (first axis) shown by a dashed line is a $\langle 001 \rangle$ crystal
25 axis. An axis Y (second axis) also shown by a dashed line is a $\langle 110 \rangle$ crystal axis.

Referring to FIG. 2, the substrate 10 has a concavity

13, which is formed by etching a bottom surface 12 of the substrate 10, to provide a diaphragm 14. A broken line in FIG. 1 also shows the diaphragm 14. The diaphragm 14 changes its shape in accordance with an application of a pressure from the top surface side or the bottom surface side. The diaphragm 14 has a square shape, and its thickness is even within a tolerance by manufacturing.

Referring to FIG. 1, four gauge resistors Ra, Rb, Rc, and Rd, which work as strain gauges, are formed on the top surface 11 by an ion-implantation or a diffusion. Resistances of the gauge resistors Ra, Rb, Rc, and Rd vary as the shape of the diaphragm 14 changes.

The four gauge resistors Ra to Rd form a bridge circuit 20 (shown in FIG. 8) in the substrate 10 in the direction of the $\langle 110 \rangle$ crystal axis (axis Y) that has good sensitivity. The gauge resistors Ra and Rd are arranged close to a center of the diaphragm 14, and referred to as central gauge resistors. The gauge resistors Rb and Rc are arranged close to a peripheral portion of the diaphragm 14 in comparison with the central gauge resistors Ra and Rd, and referred to as peripheral gauge resistors.

That is, the central gauge resistors Ra and Rd are arranged close to the center of the diaphragm 14 in comparison with the peripheral portion of the diaphragm 14. The peripheral gauge resistors Rb and Rc are arranged close to the peripheral portion of the diaphragm 14 and apart from the center of the diaphragm 14 in comparison with the central

gauge resistors Ra and Rd. The peripheral gauge resistors Rb and Rc are located outside a peripheral edge of the diaphragm 14. Opposite stresses, which are tensile stress and compressive stress, are applied to the central gauge resistors Ra and Rd and the peripheral gauge resistors Rb and Rc when a pressure applies to the diaphragm 14. Thus, the resistances of the central gauge resistors Ra and Rd and the peripheral gauge resistors Rb and Rc vary in opposite polarity.

Each of the gauge resistors Ra to Rd has a folded bar pattern. Each of them is divided into two parts so that the gauge resistors Ra, Rb, Rc, and Rd have divisional gauge resistors Ra1 and Ra2, Rb1 and Rb2, Rc1 and Rc2, and Rd1 and Rd2, respectively. The divisional gauge resistors Ra1 to Rd2 have the same resistances.

Wiring patterns H1 to H10 are formed on the top surface 11 to construct the bridge circuit 20 by connecting between the divisional gauge resistors Ra1 to Rd2 in series. The wiring pattern H1 to H10, which are formed between the divisional gauge resistors Ra1 to Rd2, are referred to as gauge wiring patterns. The gauge wiring patterns H1 to H10 are hatched in FIG. 1 to distinguish them clearly.

The gauge wiring patterns H1 to H10 are electrically connected to plugs 16, which are made of aluminums, directly or via lead wiring patterns 15. The plugs 16 are either input terminals or output terminals of the bridge circuit 20, and are electrically connected to an external circuit (not shown) via bonding wires.

The divisional gauge resistors R_{a1} to R_{d2}, the gauge wiring patterns H₁ to H₁₀, and the lead wiring patterns 15 are formed by the ion-implantation or the diffusion. The gauge wiring patterns H₁ to H₁₀ and the lead wiring patterns 15 are electrically connected to the plugs 16 via contact portions (contact holes) 17. The contact portions 17 are formed by a semiconductor process. In FIG. 1, the contact portions 17 are shown by squares with cross marks.

[Detail structures in vicinities of the gauge wiring patterns]

FIG. 3 shows a same view of FIG. 1, but the diaphragm 14 is omitted from FIG. 3 to simplify the drawing. The bridge circuit includes the gauge resistors R_a to R_d and the gauge wiring patterns H₁ to H₁₀. The gauge wiring patterns H₁ to H₁₀ are constructed of a first group of the gauge wiring patterns H₁, H₂, H₅, H₆, H₈, and H₁₀ as middle points of the bridge circuit, and a second group of the gauge wiring patterns H₂, H₄, H₇, and H₁₀. The second group of the gauge wiring patterns H₂, H₄, H₇, and H₁₀ is provided between each couple of the divisional gauge resistors R_{b1} and R_{b2}, R_{a1} and R_{a2}, R_{c1} and R_{c2}, and R_{d1} and R_{d2}, respectively.

The gauge wiring patterns H₅ and H₆ are directly connected to the plugs 16(A), and the gauge wiring patterns H₁ and H₁₀ are directly connected to the plugs 16(D). The plugs 16(A) and 16(D) are the input terminals of the bridge circuit. The gauge wiring pattern H₄ is connected to the plug 16(C₁) via the lead wiring pattern 15. The gauge wiring

pattern H9 is connected to the plug 16(C1) via the lead wiring pattern 15. The plugs 16(C1') and 16(C1) are the output terminals for a fault diagnosis. The gauge wiring pattern H4 is divided into two divisional gauge wiring patterns H41 and H42 by a boundary that is a central axis (as shown by a dashed line corresponding to the axis X) of the lead wiring pattern 15. The gauge wiring pattern H9 is also divided into two divisional gauge wiring patterns H91 and H92 by the boundary.

Referring to FIG. 4, three lead wiring patterns 15 are connected to different positions, resistances of which are different from each other, of the gauge wiring pattern H3. Each of the three lead wiring patterns 15 is connected to each one of plugs 16(Ba), 16(Bb), and 16(Bc). The plugs 16(Ba), 16(Bb), and 16(Bc) are included in the plug 16(B) that is used as one of the output terminals of the sensor S1, and are also shown as the plug 16(B) in FIG. 3.

The gauge resistor H3 is divided into four resistant areas H31, H32, H33, and H34 with respect to the three plugs 16(B). Dashed lines that correspond to central axes of the lead wiring patterns 15 show boundaries of the four resistant areas H31, 32, H33, and H34 in FIG. 4.

Referring to FIG. 5, three lead wiring patterns 15 are connected to different positions, resistances of which are different from each other, of the gauge wiring pattern H2. Each of the three lead wiring patterns 15 is connected to each one of plugs 16(B1a), 16(B1b), and 16(B1c). The plugs 16(B1a), 16(B1b), and 16(B1c) are included in the plug 16(B1) that is

used as one of the output terminals of the diagnosis, and are also shown as the plug 16(B1) in FIG. 3.

The gauge resistor H2 is divided into two resistant areas H21 and H22 with respect to the three plugs 16(B1).

5 Dashed lines that correspond to central axes of the lead wiring patterns 15 show boundaries of the two resistant areas H21 and H22 in FIG. 5.

Referring to FIG. 6, three lead wiring patterns 15 are connected to different positions, resistances of which are
10 different from each other, of the gauge wiring pattern H8. Each of the three lead wiring patterns 15 is connected to each one of plugs 16(Ca), 16(Cb), and 16(Cc). The plugs 16(Ca), 16(Cb), and 16(Cc) are included in the plug 16(C) that is used as one of the output terminals of the sensor, and are also
15 shown as the plug 16(C) in FIG. 3.

The gauge resistor H8 is divided into four resistant areas H81, H82, H83, and H84 with respect to the three plugs 16(C). Dashed lines that correspond to central axes of the lead wiring patterns 15 show boundaries of the four resistant
20 areas H81, H82, H83, and H84 in FIG. 6.

Referring to FIG. 7, three lead wiring patterns 15 are connected to different positions, resistances of which are different from each other, of the gauge wiring pattern H7. Each of the three lead wiring patterns 15 is connected to each
25 one of plugs 16(B1'a), 16(B1'b), and 16(B1'c). The plugs 16(B1'a), 16(B1'b), and 16(B1'c) are included in the plug 16(B1') that is used as one of the output terminals of the

diagnosis, and are also shown as the plug 16(B1') in FIG. 3.

The gauge resistor H7 is divided into two resistant areas H71 and H72 with respect to the three plugs 16(B1'). Dashed lines that correspond to central axes of the lead wiring patterns 15 show boundaries of the two resistant areas H71 and H72 in FIG. 7.

[A detail structure of the bridge circuit]

FIG. 8 shows an equivalent circuit of the bridge circuit 20. The equivalent circuit includes the four gauge resistors Ra to Rd (the eight divisional gauge resistors Ra1 to Rd2), and resistors of the gauge wiring patterns H1 to H10. The bridge circuit 20 includes four gauge resistors Ra (Ra1 and Ra2), Rb (Rb1 and Rb2), Rc (Rc1 and Rc2), and Rd (Rd1 and Rd2). In the bridge circuit 20, the gauge resistors Ra to Rd are connected to each other in series so that a quadrangular closed circuit constructs a Wheatstone bridge. The plugs 16, which correspond to each one of the terminals A, B, C, D, B1, and C1 in FIG. 8, are shown with parentheses such as 16(A) and 16(B) in FIG. 3 to FIG. 7.

Referring to FIG. 3, each of the input plugs 16(A) and 16(D) has two terminals. Each two terminals of the plugs 16(A) and 16(B) are electrically connected to each other, and connected to the external circuit. Each of the output terminals 16(B), 16(B1), and 16(B1') has three terminals. One of the output terminals 16(B), 16(B1), and 16(B1') is electrically connected to the external circuit.

Referring to FIG. 8, terminals A, B, C, and D are

connected to the gauge wiring patterns H1, H3, H5, H6, H8, and H10 that constitute the midpoints of the bridge circuit 20. The terminals A and D, which are opposed to each other, are used for inputting an input voltage (input signal) V_{in} . The terminals B and C, which are opposed to each other, are used for outputting a first differential voltage (output signal) V_{out1} . The input terminal A is connected to a power supply (first potential), and the input terminal D is connected to the ground (second potential).

In the bridge circuit 20, each of the gauge resistors R_a to R_d is equally divided into two divisional gauge resistors as described above. For instance, the gauge resistor R_a , which is provided between the input terminal A and the output terminal B, is divided into the two divisional gauge resistors R_{a1} and R_{a2} . Other gauge resistors R_b to R_d are divided into divisional gauge resistors R_{b1} and R_{b2} , R_{c1} and R_{c2} , and R_{d1} and R_{d2} , respectively in the same manner as the gauge resistor R_a .

Further, as described above, the resistances of the divisional gauge resistors R_{a1} , R_{a2} , R_{d1} , and R_{d2} with respect to the central gauge resistors and the divisional gauge resistors R_{b1} , R_{b2} , R_{c1} , and R_{c2} with respect to the peripheral gauge resistors vary in opposite polarity.

The gauge resistor R_a has a first midpoint between the divisional gauge resistors R_{a1} and R_{a2} , and the first midpoint is connected to a middle terminal $C1'$. The gauge resistor R_b has a second midpoint between the divisional gauge resistors

Rb1 and Rb2, and the second midpoint is connected to a middle terminal B1. The gauge resistor Rc has a third midpoint between the divisional gauge resistors Rc1 and Rc2, and the third midpoint is connected to a middle terminal B1'. The gauge resistor Rd has a fourth midpoint between the divisional gauge resistors Rd1 and Rd2, and the fourth midpoint is connected to a middle terminal C1.

The middle terminals B1 and C1 make a combination of the midpoints at which an equal electric potential is measured when no pressure is applied to the bridge circuit. The combination of the middle terminals B1 and C1 is used as the output terminals for the diagnosis. A second differential voltage Vout2 between the middle terminals B1 and C1 is used as the diagnostic output to detect a fault of the sensor. In detail, the second differential voltage Vout2 is amplified with an amplifier in the external circuit, and an output potential of the amplifier is used for the diagnosis.

[Features of the preferred embodiment]

The terminal B (i.e. plug 16(B)) is electrically connected to the gauge wiring pattern H3 that is the midpoint of the bridge circuit 20. The terminal C (i.e. plug 16(C)) is also electrically connected to the gauge wiring pattern H8 that is the midpoint of the bridge circuit 20. The middle terminals B and C are used as sensor output terminals, and the first differential voltage Vout1 is used as the sensor output to detect the intensity of the pressure. Each of the four gauge resistors Ra, Rb, Rc, and Rd is divided into the two

divisional gauge resistors Ra1 and Ra2, Rb1 and Rb2, Rc1 and Rc2, and Rd1 and Rd2, respectively.

Each of the terminal B1 (i.e. plug 16(B1)) and C1 (i.e. plug 16(C1)) is electrically connected to the gauge wiring pattern H2 and H9, respectively, that are the midpoint of the bridge circuit 20 and selected from among the gauge wiring patterns H2, H4, H7, and H9. The middle terminals B1 and C1 make a combination of the midpoints at which an equal electric potential is measured when no pressure is applied to the bridge circuit. The combination of the middle terminals B1 and C1 is used as the output terminals for the diagnosis. A second potential difference Vout2 between the middle terminals B1 and C1 is used as the diagnostic output to detect a fault of the sensor.

The output terminal B for the sensor output has three different terminals Ba, Bb, and Bc that are connected to three different positions, resistances of which are different from each other, of the gauge wiring pattern H3. The output terminal C for the sensor output has three different terminals Ca, Cb, and Cc that are connected to three different positions, resistances of which are different from each other, of the gauge wiring pattern H8.

The middle terminal B1, which is one of the output terminals for the diagnosis, has three different terminals B1a, B1b, and B1c. The different terminals B1a, B1b, and B1c are connected to three different positions, resistances of which are different from each other, of the gauge wiring pattern H2.

[Detective operation]

Referring to FIG. 8, the semiconductor dynamic quantity sensor S1 has one input V_{in} and two outputs V_{out1} and V_{out2} . The sensor S1 has the output terminals B and C for the sensor output, and the output terminals B1 and C1 for the fault diagnosis output.

When the diaphragm 14 changes its shape in accordance with the application of the pressure in condition that the input signal V_{in} is inputted into the bridge circuit 20, the four gauge resistors R_a to R_d lose a balance in electrically. The first differential voltage (output signal) V_{out1} varies in response to the amount of the applied pressure. The first differential voltage V_{out1} is supplied to the external circuit to detect the intensity of the pressure.

The fault is detected by that the first differential voltage V_{out1} is compared with the second differential voltage V_{out2} . Since each divisional gauge resistors R_{a1} to R_{d2} has the same resistance, a first ratio between the divisional gauge resistors R_{d1} and R_{d2} is 1:1, and a second ratio between the divisional gauge resistors R_{b1} and R_{b2} is 1:1. As a result, in a normal condition, the second differential voltage V_{out2} for the diagnosis is always a half voltage of the first differential voltage V_{out1} .

However, in an unusual condition that an irregular stress is applied to the diaphragm 14 or the divisional gauge resistors R_{a1} to R_{d2} are broken, the first ratio and the second ratio are deviated from 1:1. As a result, in the

unusual condition, the second differential voltage Vout2 for the diagnosis is not a half voltage of the first differential voltage Vout1. That is, a relation between the differential voltages Vout1 and Vout2 in the unusual condition is different from the relation in the normal condition. This provides the judgment of the fault in the sensor S1.

If the diagnostic output Vout2 is not provided in the sensor S1 and the sensor S1 produces only the sensor output Vout1, a reason of the variation cannot be judged when the sensor output Vout1 varies to a certain voltage, such as zero. The reason includes at least one of whether the diaphragm 14 is damaged, the gauge resistors Ra to Rd are broken, the external circuit has a fault, or the pressure is actually zero.

However, since the diagnostic output Vout2 is provided in the sensor S1, the sensor S1 does not have such a problem. For instance, when the sensor output Vout1 varies to zero and diagnostic output Vout2 is equal to zero, the reason is correctly judged that the fault is not occurred and the pressure is actually equal to zero.

According to the present invention, each of the four gauge resistors Ra to Rd that forms the bridge circuit 20 is divided into the two divisional gauge resistors Ra1 to Rd2. The middle terminals B1 and C1 are connected to the midpoint between the couple of divisional gauge resistors to make a combination of the midpoints at which equal electric potential is measured when no pressure is applied to the bridge circuit 20. The second differential voltage Vout2 between the middle

terminals B1 and C1 is used for the diagnosis. Accordingly, the sensor S1 can detect the intensity of the pressure and the fault of the sensor S1 by the single bridge circuit.

[Adjustment of the offset voltage]

5 Offset voltages exist in both the first differential voltage Vout1 for the sensor output and the second differential voltage Vout2 for the diagnostic output in the bridge circuit 20 in reality. The offset voltages, which are generated by the sensor and diagnostic outputs when the
10 pressure is not applied to the diaphragm 14, are cause of errors to detect the pressure and the fault. If resistances of the gauge wiring patterns H1 to H10 that connect between the divisional gauge resistors Ra1 to Rd2 in the bridge circuit 20 are zero or the identical in an ideal condition, the offset
15 voltages are not produced. However, the offset voltages are produced in reality.

 Under the condition in reality, each of the output terminals B and C for the sensor output has plurality (three) selectable output terminals Ba, Bb, and Bc, and Ca, Cb, and Cc.
20 The output terminal B1 for the diagnostic output, which is one of the output terminals B1 and C1 for the diagnostic output, has plurality (three) selectable output terminals B1a, B1b, and B1c. That is, the output terminal B, C, and B1 are selectable. Accordingly, combinations of the selectable output
25 terminals for the sensor output and the diagnostic output can be selected in accordance with the condition.

When the combination is appropriately selected from

among the plurality selectable output terminals, the offset voltages are adjusted as appropriate to bring the offset voltages close to zero in condition that the sensor output and the diagnostic output do not influence each other. For example, suppose that the offset voltage of the second differential voltage V_{out2} is equal to zero, and the offset voltage of the first differential voltage V_{out1} is a certain voltage that is not equal to zero. In addition, suppose that the selectable output terminals Bb and Cb for the sensor output are selected.

The connection of the output terminal C is changed from the selectable output terminal Bb to other terminal Ba or Bc so that the offset voltage of the sensor output can be adjusted as appropriate in a certain condition. The certain condition is that the selectable output terminal Cb is still selected from among the output terminal C.

In detail, referring to FIG. 4, the connection of the plug 16(B) is changed from the plug 16(Bb) to the plug 16(Ba) or the plug 16(Bc). Lengths L_1 , L_2 , L_3 , and L_4 of the four divisional resistant areas H31 to H34, and a width W_1 of that are shown in FIG. 4. A symbol " ρ_s " is a sheet resistance of that.

When the connection of the output terminal B is changed from the terminal Bb to Ba, a present output voltage from the terminal Ba increases by a certain voltage $\rho_s \cdot (L_2/W_1)$ in comparison with a previous output voltage from the terminal Bb. When the connection of the output terminal B is changed from the terminal Bb to Bc, a present output voltage from the

terminal Bc decreases by a certain voltage $\rho s \cdot (L3/W1)$ in comparison with the previous output voltage from the terminal Bb. That is, when the connection of the output terminal B is changed from the terminal Bb to Ba or Bc to adjust the offset
5 voltage of the sensor output, the offset voltage is varied with $\rho s \cdot (L2/W1)$, or $\rho s \cdot (L3/W1)$.

The resistance between the input terminals A and D is not changed even when the connection of the output terminal B is changed. Thus, an electrical current between the input
10 terminals A and D are not changed. As a result, the selection of the output terminal B does not influence an electrical potential of the diagnostic output terminal (middle terminal) B1, and the electrical potential of the output terminal B1 does not vary.

15 This is the same when the connection of the output terminal C is changed. As a result, the offset voltage of the sensor output becomes close to zero when the combination of the output terminals B and C for the sensor output is selected appropriately.

20 This is the same in an adjustment of the offset voltage of the diagnostic output. For example, suppose that the offset voltage of the first differential voltage V_{out1} is equal to zero, and the offset voltage of the second differential voltage V_{out2} is a certain voltage that is not
25 equal to zero. In addition, suppose that the output terminals B1b and C1 for the diagnostic output are selected. The connection of the terminal B1 is changed from the selectable

output terminal B1b to other terminal B1a or B1c so that the offset voltage of the diagnostic output can be adjusted as appropriate.

In detail, referring to FIG. 5, the connection of the plug 16(B1) is changed from the plug 16(B1b) to the plug 16(B1a) or the plug 16(B1c). Lengths L5 and L6 of the two divisional resistant areas H21 and H22, and a width W2 of that are shown in FIG. 5. A symbol " ρ_s " is a sheet resistance of that.

When the connection of the output terminal B1 is changed from the terminal B1b to B1a, a present output voltage from the terminal B1a increases by a certain voltage $\rho_s \cdot (L5/W2)$ in comparison with a previous output voltage from the terminal B1b. When the connection of the output terminal B1 is changed from the terminal B1b to B1c, a present output voltage from the terminal B1c decreases by a certain voltage $\rho_s \cdot (L6/W2)$ in comparison with the previous output voltage from the terminal B1b. That is, when the connection of the output terminal B1 is changed from the terminal B1b to B1a or B1c to adjust the offset voltage of the diagnostic output, the offset voltage is varied with $\rho_s \cdot (L5/W2)$, or $\rho_s \cdot (L6/W2)$.

The resistance between the input terminals A and D is not changed even when the connection of the output terminal B1 is changed. Thus, the electrical current between the input terminals A and D are not changed. As a result, the selection of the output terminal B1 does not influence the electrical potential of the sensor output terminal B, and the electrical

potential of the output terminal B does not vary. Therefore, the offset voltage of the diagnostic output becomes close to zero when the combination of the output terminal B1 and C1 for the diagnostic output is selected appropriately.

5 For selecting the output terminal appropriately to adjust the offset voltage, an inspection of the bridge circuit 20 is performed in advance of a connection between the terminals and the external circuit. Then, the appropriate output terminals are connected to the external circuit by a
10 wire bonding.

 The present invention should not be limited to the embodiments previously discussed and shown in the figures, but may be implemented in various ways without departing from the spirit of the invention. For example, in the foregoing
15 embodiment, each of the output terminals B, C, and C1 for the sensor output and the diagnostic output has three selectable output terminals. However, each of the output terminals B, C, and C1 may have two or not less than four selectable output terminals. When the output terminals have not less than three
20 selectable output terminals, variations of the offset voltages are easily determined as to whether the variations are linear or nonlinear. This causes easiness to pick out a zero point of the offset voltage.

 A differential voltage between any two middle
25 terminals can be used as the diagnostic output if the electric potentials of the middle terminals are the same in a condition that the pressure is not applied. For example, referring to

FIG. 8, the sensor S1 has middle terminals B1' and C1'. The middle terminal B1' is connected to the midpoint between the divisional gauge resistors Rc1 and Rc2. The middle terminal C1' is connected to the midpoint between the divisional gauge resistors Ra1 and Ra2. The middle terminals B1' and C1' can be used as the diagnostic output in the sensor S1.

A third differential voltage Vout2' between the middle terminals B1' and C1' is used as the second diagnostic output. If the middle terminal B1' has three selectable output terminals Bla', B1b', and B1c', the offset voltage of the diagnostic output is adjusted in the same manner as the middle terminal B1.

The offset voltage may be adjusted so that the offset voltage is close to a certain voltage according to a requirement of the circuit. The certain voltage is not a zero but a high voltage.

In the foregoing embodiment, only one middle terminal B1 in the output terminals B1 and C1 for the diagnosis is constructed of plurality selectable output terminals Bla, B1b, and B1c. Similarly, only one middle terminal B1' in the output terminals B1' and C1' for the diagnosis is constructed of plurality selectable output terminals. However, each of the other middle terminals C1 and C1' may have plurality selectable output terminals.

In the foregoing embodiment, each of the four gauge resistors Ra to Rd is divided into the two divisional gauge resistors. However, each of the gauge resistors Ra to Rd may

be divided into three or more divisional gauge resistors. When the gauge resistors Ra to Rd are divided into three or more divisional gauge resistors, an equal combination is used as the output terminals for the diagnosis, and a differential voltage between the output terminals is used as the diagnostic output. The equal combination is a combination of midpoints, which are connections among the three or more divisional gauge resistors, at which equal electric potential is measured.

The sensor S1 is applicable to a semiconductor pressure sensor. The semiconductor pressure sensor includes a metal sleeve that has a thin closed end portion and an open-end portion. The thin closed end portion is formed at one side of the metal sleeve, and it has a thin portion on which the semiconductor substrate is arranged. The open-end portion is formed at the other side of the metal sleeve, and it introduces a pressure to the thin closed end portion. The thin closed end portion changes its shape by applying the pressure, and then the semiconductor itself also changes its shape as the diaphragm by the change of the thin closed end portion.

Moreover, the sensor S1 is applicable to an acceleration sensor that has a diaphragm, which changes its shape by applying a shock when acceleration is applied to the sensor S1. The acceleration sensor detects a stress in the diaphragm with gauge resistors.